



Energy, Mines and
Resources Canada

Énergie, Mines et
Ressources Canada

CANMET

Canada Centre
for Mineral
and Energy
Technology

Centre canadien
de la technologie
des minéraux
et de l'énergie

CARBONIZATION OF CONVENTIONAL AND PARTIALLY BRIQUETTED CHARGES OF A CANADIAN STEEL COMPANY BLEND CONTAINING WESTERN CANADIAN COALS

J.T. Price and J.F. Gransden
Combustion and Carbonization Research Laboratory

October 1985

This document is an unclassified
internal report prepared primarily
for discussion and internal
reporting purposes. It does not
represent a final statement of
the opinion of the author, and
for Mineral and Energy Technology
(CANMET).

Ce document est un rapport
non classifié préparé et rédigé
principalement pour fins de
discussion et de documentation
interne. Il ne constitue pas une
déclaration officielle de
l'opinion de l'auteur et de
la Technologie des minéraux et de
l'énergie (CANMET).

17pp
ENERGY RESEARCH PROGRAM
ENERGY RESEARCH LABORATORIES
DIVISION REPORT ERP/ERL 85-58(TR)

MICROMEDIA

CARBONIZATION OF CONVENTIONAL AND PARTIALLY BRIQUETTED
CHARGES OF A CANADIAN STEEL COMPANY BLEND
CONTAINING WESTERN CANADIAN COALS

by

J.T. Price* and J.F. Gransden*

ABSTRACT

Pilot-scale carbonization tests were conducted to evaluate the suitability of Western Canadian coking coals for use in blends used by Canadian steel companies. Carbonization of conventional and 30% partially briquetted charges was investigated using two Western coals each blended with a Canadian steel company coal. Both coals when carbonized 30% partially briquetted largely improved coke quality (8 stability units) with minimal increase in coking pressure compared with conventional charges. Partially briquetting the steel company blend produced excessive coking pressure under carbonization test conditions. Inclusion of Western coals into partially briquetted blends did not reduce coking pressures significantly. For the blends investigated partial briquetting was not needed and excellent metallurgical coke was produced at lower coking pressures by utilizing 50% Western coals in conventional charges. One coke had an ASTM stability of 62, CSR of 56, and CRI of 29. All are considered excellent for test oven coke.

* Research Scientists, Combustion and Carbonization Research Laboratory
Energy Research Laboratories, CANMET, Energy, Mines and Resources Canada,
Ottawa, K1A 0G1

CARBONISATION DE CHARGES CLASSIQUES OU PARTIELLEMENT AGGLOMÉRÉES
COMPOSÉES D'UN MÉLANGE CONTENANT DES CHARBONS DE L'OUEST CANADIEN
EN PROVENANCE D'UNE ACIÉRIE CANADIENNE

par

J.T. Price* et J.F. Gransden*

RÉSUMÉ

Des essais de carbonisation à l'échelle-pilote ont été menés en vue de déterminer si les charbons cokéfiants de l'ouest du Canada peuvent être inclus dans les mélanges utilisés par les aciéries canadiennes. On a investi-gué la carbonisation de charges classiques et de charges agglomérées partiel-lement à 30 % en utilisant deux charbons de l'Ouest et en mélangeant chacun d'entre eux à un charbon provenant d'une aciérie canadienne. Lorsqu'ils ont été carbonisés et agglomérés partiellement à 30 %, les deux charbons ont grandement amélioré la qualité du coke (indice de stabilisation de 8) et la pression de cokéfaction n'a dû être augmentée que de façon minimale par rapport aux charges classiques. L'agglomération partielle du mélange prove-nant de l'aciérie a accru la pression de cokéfaction de façon excessive dans des conditions d'essai de carbonisation. L'introduction de charbons de l'Ouest dans les mélanges partiellement agglomérés n'a pas réduit la pression de cokéfaction de façon significative. L'agglomération partielle des mélanges étudiés n'était pas nécessaire et un excellent coke métallurgique a été produit à des pressions de cokéfaction plus basses en utilisant des charbons canadiens dans une proportion de 50 % dans les charges classiques. Un des cokes a démontré un indice de stabilité de 62 selon la norme ASTM, de 56 selon CSR et de 29 selon CRI. On estime que tous les charbons se prêtent très bien aux essais de cokéfaction.

* Chercheur scientifique, Laboratoire de recherche sur la carbonisation et la combustion, Laboratoires de recherche sur l'énergie, CANMET, Énergie, Mines et Ressources Canada, Ottawa, K1A 0G

INTRODUCTION

Most Canadian metallurgical coking coals are found in Alberta and British Columbia and are mined for export primarily to Japan and other Pacific Rim countries for the production of metallurgical coke. In Japan, much of the metallurgical coke is produced by an adaptation of conventional cokemaking technology and partially briquetting the coke oven charge.

Canadian steel companies have not used Western Canadian coals extensively and generally use blends of high- and low-volatile bituminous coals from the Appalachian coalfields which have better proximity to the Ontario steel mills. Although investigations through the Canadian Carbonization Research Organization (CCRA) have shown that improvements to coke quality or coke oven productivity can be achieved by partially briquetting Canadian steel company blends (1,2) companies use conventional technology because they are concerned about the coking pressures that may develop during carbonization of high density Appalachian coal charges.

Carbonization of conventional and partially briquetted charges at CANMET have shown that high-inert Western coals usually have low coking pressures. Also, by partially briquetting some of these coals, coke quality improved markedly compared with that of the conventional charge (3).

Therefore, a preliminary study was made to determine if Western coals can be used to advantage in either conventional or partially briquetted blends used by Canadian steel companies. Two medium volatile Western coals were investigated with a typical blend from a Canadian steel company.

EXPERIMENTAL PROCEDURE

Carbonization tests were conducted in CANMET's movable wall test oven having a coking chamber 457 mm wide, 914 mm long, and 914 mm high to the coal levelling door sill, and a charge capacity of 325 kg. The oven flue temperature was maintained at either 1125 or 1200°C by electrically heated globars with heat transferred to the coal charge through high density silica bricks similar to those used industrially. The oven was charged with coal containing 3-6% moisture having a nominal pulverization level of $80 \pm 5\%$ minus 3 mm, resulting in a bulk density of 744 or 850 kg/m³ (dry basis). About 18 h is required to carbonize the charge to a centre temperature of 1000°C.

The matrix coal for 30% partially briquetted charges was prepared identically to that for conventional charging and was sampled for rheological and petrographic analyses. The coal or blend for briquetting was pulverized nominally to 90% minus 1 mm, mixed with 6% PDA asphalt (softening point 77°C) in a double-arm kneader-mixer heated to 100°C, then briquetted in a double roll press which produced 30 x 30 x 18 mm pillow-shaped briquets. Briquet moisture at the time of charging was 1.2-1.8%.

After carbonization the coke is pushed from the oven, water quenched, dropped 3 m to simulate commercial coke handling, dried, screened, and tested for coke strength according to ASTM and JIS Tumbler Methods (4,5). Coke strength after reaction (CSR) tests were made on selected cokes (6).

RESULTS

COAL PROPERTIES

Table 1 lists chemical properties of the two Western coals and Table 2 lists the petrographic properties of the Western coals and the steel company blends.

Coal A has petrographic balance and strength indices similar to those of the industrial blend whereas coal B has higher vitrinite reflectance, and higher inerts thus higher strength and balance indices.

Table 3 compares the thermal rheological properties of the steel company blend with the blends containing 50% of Western coal. Inclusion of Western coals in the blend reduced the maximum Gieseler plasticity substantially but had only minor influences on the Ruhr dilatation and FSI.

Table 1 - Chemical Analysis of Two Western Coals

	Coal A	Coal B
Proximate analysis, %		
Ash	9.3	10.0
Volatile matter	25.0	21.1
Fixed carbon	65.7	68.9
Ultimate analysis, %		
Carbon	80.6	81.6
Hydrogen	4.5	4.2
Sulphur	0.55	0.27
Nitrogen	1.6	1.2
Ash	9.3	10.0
Oxygen	3.4	2.7

Table 2 - Petrographic analysis of Western coals A and B and company blend

	100% Coal Blend A	100% Coal Blend B	Steel Company Blend
<u>Vitrinite distribution, %</u>			
V-5	.0	-	.2
V-6	.0	-	1.4
V-7	.0	-	11.4
V-8	.7	-	18.7
V-9	6.0	-	16.0
V-10	25.2	-	2.7
V-11	29.2	-	.3
V-12	4.7	4.9	.2
V-13	.7	25.1	.5
V-14	.0	11.9	1.2
V-15	.0	2.2	3.9
V-16	.0	-	5.8
V-17	.0	-	5.4
V-18	.0	-	.3
<u>Reactive components</u>			
Vitrinite	66.4	44.1	67.9
Semi-fusinite reactives	10.2	17.7	3.8
Exinite	.4	0.0	6.5
Total reactives	77.0	61.8	78.2
<u>Inert components</u>			
Semifusinite	10.2	17.7	7.6
Micrinite	3.1	7.3	7.4
Fusinite	4.5	7.7	3.3
Mineral matter	5.2	5.5	3.5
Total inerts	23.0	38.2	21.8
<u>Petrographic indices, %</u>			
Mean reflectance	1.10	1.38	1.06
Balance index	.88	3.54	.94
Strength index	4.19	5.82	4.19
stability index	58.4	48.1	58.2

Table 3 - Thermal rheological properties of Western coals and blends investigated

Identification Blend	Company blend	100% coal A	100% coal B	50% company blend 50% coal A	50% company blend 50% Coal B	71% company 29% coal Blend
<u>Gieseler plasticity</u>						
Start.....°C	407	431	438	418	412	412
Fusion temp°C	419	446	453	432	429	424
Max. Fluid temp°C	440	463	470	451	448	449
Final Fluid temp°C	472	481	493	475	473	474
Solidification temp°C	480	486	495	482	482	484
Melting range°C	65	50	55	57	56	62
Max. fluidity.....dd/m	280.3	25.2	46	21.3	34.5	71
<u>Dilatation</u>						
Ti - Softening temp.....°C	384	405	408	395	386	386
Tii - Max. contraction temp...°C	426	450	458	442	439	433
Tiii - Max. dilatation temp...°C	462	476	482	471	470	465
Contraction.....%	26	25	21	24	28	26
Dilatation%	14	12	4	8	16	10
<u>Free swelling index</u>						
P.S.I.	6	7.5	7	5	6	5

CARBONIZATION OF CONVENTIONAL AND 30% PARTIALLY
BRIQUETTED WESTERN CANADIAN COAL CHARGES

Tables 4 and 5 compare the coking results from conventional and partially briquetted Western coal charges. Coke quality (ASTM stability) from the partially briquetted Western coals improved markedly (about 8 stability units) compared with that of the conventional charges and is consistent with results obtained previously for other Western coals (7). Coking pressures remained low for all charges except when the higher rank coal B was charged 30% partially briquetted at low (3%) moisture and carbonized at the higher flue temperature (coking rate). These results suggest that existing Western Canadian coals are ideally suited for blending in partial briquetting processes.

Table 4 - Results of conventional and partially briquetted coking trials for coal A

Description.....	Conventional charges	Partially Briquetted charges
Charge properties		
Moisture in charge	5.9	4.4
Minus 3.35 mm	86.1	90.3
Carbonization conditions		
Net weight of charge (wet).....kg	315	338
ASTM cone bulk density (wet).....kg/m ³	39.8	39.5
Calc. charge dry bulk density in oven... kg/m ³	730	712
Flue Temp Control	1125	1125
Carbonization results		
Gross coking time (at Push).....h:min	16:55	18:05
Final centre temp.....°C	1000	990
Time to 900°C centre temp..... h:min	15:30	17:19
Maximum wall pressure.....kPa	2.1	3.2
Coke yield actual	72.2	74.4
Screen analysis of coke		
(cum. % retained on)		
102 mm sieve.....%	3.1	2.3
76 mm sieve.....%	17.9	15.3
5 mm sieve.....%	61.1	59.1
38 mm sieve.....%	81.6	82.5
25 mm sieve.....%	92.4	94.0
19 mm sieve.....%	93.6	96.1
13 mm sieve.....%	94.5	96.2
Percentage -13 mm sieve (breeze)	5.5	3.9
Mean coke size.....mm		
Coke chemical analysis		
Proximate analysis (db)		
Ash.....%	12.0	11.8
Volatile matter.....%	0.5	0.8
Fixed carbon.....%	87.5	87.4
Sulphur (db).....%	0.51	0.51
Coke apparent specific gravity.....	0.841	0.907
ASTM coke tumbler test		
Stability factor (cum. % + 25 mm).....	49.3	57.9
Hardness factor (cum. % + 6 mm).....	56.3	65.1
JIS coke tumbler test		
(cum. % retained on)		
30 revs: 15 mm sieve.....	92.1	93.4
150 revs: 15 mm sieve.....	77.0	81.5
CSR	28.0	-
CRI	45.0	55.1

Table 5 - Results of conventional and partially briquetted coking trials for coal B

Description.....	Conventional Charges		Partially briquetted charges	
Charges				
Moisture in charge	5.9	6.0	2.9	4.8
Minus 3.35 mm	92.8	92.8	92.8	95.1
Carbonization conditions				
Net weight of charge (wet).....kg	319.1	317.3	363.6	340.1
ASTM cone bulk density (wet).....kg/m ³	682.0	672.0	800	-
Calc. charge dry bulk density in oven... kg/m ³	734.0	731.2	868.2	794
Flue Temp Control	1125	1125	1200	1125
Carbonization Results				
Gross coking time (at push).....h:min	18:20	18:30	18:20	19:50
Final centre temp.....°C	978	993	1002	977
Time to 900°C centre temp..... h:min	16:40	15:55	16:38	17:30
Maximum wall pressure.....kPa	1.52	1.65	5.2	3.10
Coke yield actual	78.1	76.8	77.4	78.0
Screen analysis of coke (cum. % retained on)				
102 mm sieve.....%	8.2	10.0	3.3	6.3
76 mm sieve.....%	28.0	30.2	17.5	27.8
5 mm sieve.....%	68.0	69.3	56.1	66.0
38 mm sieve.....%	84.0	85.5	77.6	85.2
25 mm sieve.....%	93.4	93.7	90.9	94.6
19 mm sieve.....%	94.2	94.5	92.1	95.4
13 mm sieve.....%	94.9	95.3	93.0	96.1
Percentage -13 mm sieve (breeze)	5.1	4.7	7.0	3.9
Mean coke size..... mm	63.5	64.5	55.6	62.7
Coke chemical analysis				
Proximate analysis (db)				
Ash.....%	12.1	-	11.9	12.0
Volatile matter.....%	1.4	-	1.4	1.3
Fixed carbon.....%	86.5	-	86.7	86.7
Sulphur (db).....%	0.28	-	0.30	0.30
Coke apparent specific gravity.....	0.917	0.919	0.977	0.976
ASTM coke tumbler test				
Stability factor (cum. % + 25 mm).....	55.3	56.2	54.2	62.5
Hardness factor (cum. % + 6 mm).....	61.6	61.4	62.2	69.0
JIS coke tumbler test				
(cum. % retained on)				
30 revs: 15 mm sieve.....	91.5	92.8	92.0	94.0
150 revs: 15 mm sieve.....	77.3	80.1	78.5	83.8
Other				
CSR	44.1	-	59.4	-
CRI	29.0	-	30.0	-

COMPARISON OF COKING RESULTS OF CONVENTIONALLY CHARGED
COMPANY BLENDS CONTAINING UP TO 50% WESTERN CANADIAN COALS

Table 6 shows coking results for conventionally charged blends of steel company plus Western coals. Tests were done at 3% moisture and 1200°C flue temperature in order to observe better the effects of the coal types on carbonization pressures. Results indicate that inclusion of 50% of either of the Western coal A or B in the conventional charges decreased the coking pressure from about 8 to 4-5 kPa. Cokes made from the blend containing 50% coal A had higher yield, improved ASG, better CSR and CRI indices, similar coke stability, but a slightly poorer ASTM hardness factor than coke made from only the steel company blend. Coke results from blends containing 50% coal B showed coke yield ASG, ASTM stability, hardness, CSR and CRI had either improved or remained about the same as those from coke made from the company blend.

Table 6 - Results of conventional carbonization of blends containing steel company and Western coals

CHARGE PROPERTIES	100% company blend	50% company blend 50% coal A	50% company blend 50% coal B
Moisture in charge	3.1	3.1	3.0
Minus 3.35 mm	88.0	89.4	86.5
Carbonization conditions			
Net weight of charge (wet).....kg	358.4	358	344.5
ASTM cone bulk density (wet).....kg/m ³	799	-	-
Calc. charge dry bulk density in oven... kg/m ³	854	853	821
Flue temp control	1200	1200	1200
Carbonization results			
Gross coking time (at push).....h:min	17:05	17:45	18:30
Final centre temp.....°C	990	1000	1014
Time to 900°C centre temp..... h:min	15:43	16:33	16:32
Maximum wall pressure.....kPa	8.3	4.69	5.5
Coke yield actual	72.8	73.8	-
Screen analysis of coke (cum. % retained on)			
102 mm sieve.....%	2.3	2.1	2.9
76 mm sieve.....%	17.8	15.7	16.8
50 mm sieve.....%	58.2	54.3	58.3
38 mm sieve.....%	80.2	80.7	81.2
25 mm sieve.....%	94.5	95.8	94.7
19 mm sieve.....%	95.8	95.8	95.8
13 mm sieve.....%	96.7	96.6	96.4
Percentage -13 mm sieve (breeze)	3.3	3.4	3.6
Mean coke size.....mm	57.2	55.9	57.2
Coke apparent specific gravity.....	0.869	0.934	0.979
ASTM coke tumbler test			
Stability factor (cum. % + 25 mm).....	61.8	61.9	62.4
Hardness factor (cum. % + 6 mm).....	70.8	68.4	71.2
JIS coke tumbler test (cum. % retained on)			
30 revs: 15 mm sieve.....	95.0	94.3	94.2
150 revs: 15 mm sieve.....	85.2	84.1	84.4
Other			
CSR	54.0	56.2	52.6
CRI	34.8	29.2	34.7

PARTIALLY BRIQUETTED CHARGES OF STEEL COMPANY BLENDS
CONTAINING WESTERN CANADIAN COALS

Carbonization results in Table 7 for 30% partially briquetted coke oven charges show coke quality improved considerably from that of similar charge compositions coked conventionally (Table 6). Partial briquetting increased the coking pressures to dangerously high levels at the coking conditions used. At a coal bulk density of 925-932 kg/m³ (Table 7), the incorporation of Western coals A and B decreased coking pressure slightly from 17.4 to 15.2 and 12.2 kPa respectively. The coke oven charge at the higher coal bulk density (951 kg/m³) resulted in even higher pressures (23.2 kPa) even with the inclusion of 50% coal A or B.

Incorporating 50% Western coal A into a partially briquetted blend of steel company coal had little effect on the coke quality parameters since all cokes were excellent. Coke reactivity (CRI), CSR, and coke ASG improved but the ASTM and JIS tumbler indices decreased slightly from those of the partially briquetted steel company blend. Incorporating coal B into partially briquetted charges generally maintained or improved the ASTM and JIS indices over that of the company blend with partial briquetting. It would appear that blending the company blend with 50% coal B prior to briquetting gives a more superior coke quality than those obtained by incorporating only Western coal in the briquets.

Table 7 - Carbonization results of 30% partially briquetted charges made from company blends containing up to 50% Western coal

	100% company blend	50% company blend 50% coal A	50% company blend 50% coal B	Charge X*
<u>Charge properties</u>				
Moisture in charge	2.4	2.6	2.5	2.5
Minus 3.35 mm	91.6	92.6	90.6	93.7
<u>Carbonization conditions</u>				
Net weight of charge (wet).....kg	385	389	397	388
Calc. charge dry bulk density in oven... kg/m ³	925	931.2	951	931
Flue temp control	1200	1200	1200	1200
<u>Carbonization results</u>				
Gross coking time (at push).....h:min	18:50	18:30	19:12	18:58
Final centre temp.....°C	1005	986	995	999
Time to 900°C centre temp..... h:min	16:37	16:50	17:34	17:05
Maximum wall pressure.....kPa	17.4	15.2	23.2	12.2
Coke yield actual	71.8	74.6	76.0	75.7
<u>Screen analysis of coke</u>				
(cum. % retained on)				
102 mm sieve.....%	3.4	1.5	3.8	2.4
76 mm sieve.....%	16.5	12.8	17.1	15.9
50 mm sieve.....%	51.9	51.9	53.0	53.0
38 mm sieve.....%	77.1	79.6	78.9	80.4
25 mm sieve.....%	94.8	95.1	94.9	94.8
19 mm sieve.....%	96.3	96.4	96.1	96.4
13 mm sieve.....%	97.2	97.2	96.9	97.2
Percentage -13 mm sieve (breeze)	2.8	2.8	3.1	2.8
Mean coke size.....mm	55.6	54.4	55.8	55.8
Coke apparent specific gravity.....	0.906	0.955	0.995	0.980
<u>ASTM coke tumbler test</u>				
Stability factor (cum. % + 25 mm).....	64.2	62.7	67.0	64.2
Hardness factor (cum. % + 6 mm).....	72.5	71.4	74.0	73.0
<u>JIS coke tumbler test</u>				
(cum. % retained on)				
30 revs: 15 mm sieve.....	95.8	93.9	94.9	95.3
150 revs: 15 mm sieve.....	86.0	84.3	86.2	86.0
<u>Other</u>				
CSR	60.5	62.8	61.0	57.0
CRI	31.6	27.3	31.7	33.7
* 70% loose coal (71% company blend + 29% coal B)				
30% briquets (100% coal B)				

* 70% loose coal (71% company blend + 29% coal B)
30% briquets (100% coal B)

SUMMARY

Western Canadian coals can be readily added to a typical conventionally charged Canadian steel company blend without serious consequences. Western coals A and B decreased coking pressures when blended with the company blend and carbonized conventionally. The addition of the higher rank Western coal B gave improved yields and slight improvement to the ASTM stability factor for both conventional and partially briquetted coke oven charges. The addition of coal A would appear useful for improving the coke reactivity and CSR while decreasing coking pressures.

Partially briquetting Canadian steel company coke oven charges may result in high coking pressures. Inclusion of Western coals such as coal A decreased coking pressures but not enough to encourage this technology to be used industrially (at least at the coal bulk densities and heating rates used in this investigation). For the blends investigated partial briquetting technology is not required; conventional charges containing 50% Western coal gave a coke ASTM stability of 62, CSR value of 56 and CRI of 29.2. All are considered excellent for test oven cokes.

REFERENCES

1. Price, J.T., Gransden, J.F., Leeder, W.R. and Kay, A.
"Partial briquetting of coke-oven charges"; Proceedings of Ironmaking Conf; Washington; Vol 39, 176-185; 1980.
2. Price, J.T. and Gransden, J.F. "Effect of heating rate on productivity, coke quality and coking pressures from conventionally and partially briquetted charges carbonized in CANMET's pilot scale coke oven"; Division Report ERP/ERL 82-50 (TR).
3. Price, J.T., Gransden, J.F. and Leeder, W.R. "Canadian R&D studies of partially briquetted coke oven charges"; Energy, Mines and Resources Canada, CANMET Report 82-8E; 1982.
4. American Society of Testing and Materials Book of ASTM Standards, Standard Method of Tumbler Test for Coke, Part 26, D294-64; 41-42; 1974.
5. Japanese Industrial Standard. Japanese Testing Method for Coke Strength. JIS K2151.
6. Murakami, S., Hara, Y. and Ishikawa, I. "New ideas about coke reactivity"; Coke Circular 23:2:82-87; 1974.
7. Price, J.T. and Gransden J.F. "Improvement to coke quality through partially briquetting Western Canadian coals"; Proceedings 18th Biennial Conference of the Institute for Briquetting and Agglomeration, Vol 18, 193-199; 1983.

